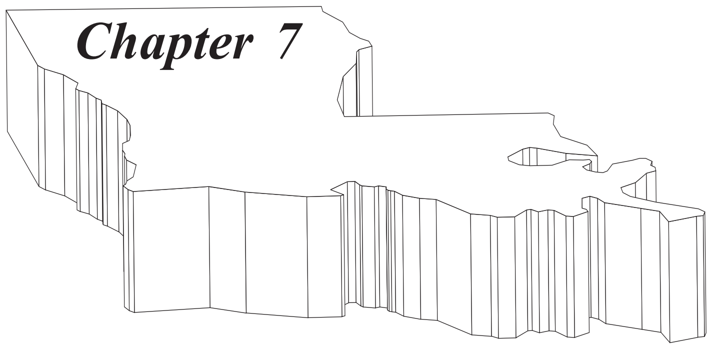
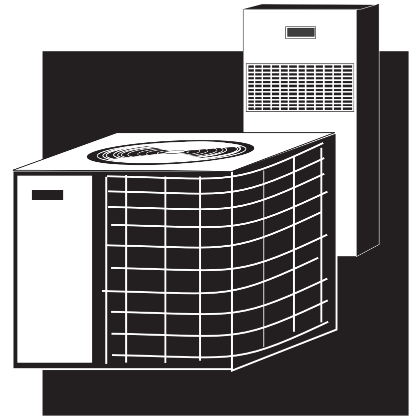




Heating, Ventilation, Air Conditioning (HVAC)

One of the most important decisions regarding a new home is the type of heating and cooling system to install. Equally critical is the heating and cooling contractor selected, as the operating efficiency of a system depends as much on proper installation as it does on the performance rating. Keys to obtaining the design efficiency of a system in the field include:

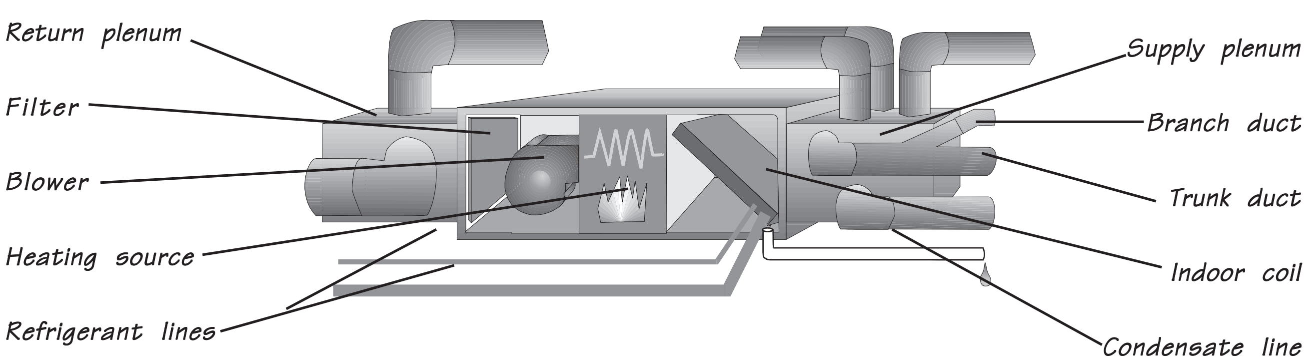
- Sizing and selecting the system for the heating, cooling, and dehumidification load of the home being built
- Correct design of the ductwork or piping
- Proper installation and charging
- Insulating and sealing all ductwork or piping

Improper installation of components, in particular of ductwork, has negative impacts on comfort and energy bills and can dramatically degrade the quality of air in a home. Poorly designed and installed ducts can create dangerous conditions that may reduce comfort, degrade indoor air quality, or even threaten the lives of the homeowners.

Types of HVAC Systems

There are two primary types of central heating systems — forced-air systems and radiant heating systems. Most new homes have *forced-air heating and cooling systems* — either using a central furnace and air conditioner or a heat pump. Figure 7-1 shows that in forced-air systems, a series of *ducts* distribute the conditioned heated or cooled air throughout the home. The conditioned air is forced through the ducts by a *blower*, located in a unit called an *air handler*.

Figure 7-1
Components of Forced-air Systems



Most homes in Louisiana have two choices for central, forced-air systems: fuel-fired furnaces with electric air conditioning units or electric heat pumps. The best system for each home depends on many factors -- cost, comfort, efficiency, annual energy use, availability, and local prices for fuels and electricity.

When considering a HVAC system for a residence, remember that energy efficient homes have less demand for heating and cooling, so substantial cost savings may be obtained by installing smaller units that are properly sized to meet the load. Because energy bills in more efficient homes are lower, higher efficiency systems will not provide as much annual savings on energy bills and may not be as cost effective as in less efficient homes. A home with annual heating and cooling bills of only $700 will find it hard to justify a 20% more efficient HVAC system that costs an extra $2,000 or $3,000. The payback period will exceed 13 years.

Sizing

It is important to size heating and air conditioning systems properly. Not only does oversized equipment cost more, but it can waste energy and may decrease comfort. For example, an oversized air conditioner cools a house but may not provide adequate dehumidification, thus creating cool, but clammy air.

Do not rely on rule-of-thumb methods to size HVAC equipment. Many contractors select air conditioning systems based on a rule such as 500 square feet of cooled area per ton of air conditioning (a ton provides 12,000 Btu per hour of cooling). Instead, use a sizing procedure such as:

- ❒ Calculations in *Manual J* published by the Air Conditioning Contractors Association
- ❒ Similar procedures developed by the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE)
- ❒ Software procedures developed by electrical or gas utilities, the U.S. Department of Energy, HVAC equipment manufacturers, or private software companies

The heating and cooling load calculations rely on the size and type of construction for each component of the building envelope, as well as the heat given off by the lights, people, and equipment inside the house. If a zoned heating and cooling system is used, the loads in each zone should be calculated separately.

Table 7-1
Equipment Sizing and Cost Comparison

Type of House	More Efficient	Less Efficient
R-Values and Areas		
Attic [Area/R-value]	2,000 sq ft R-38	2,000 sq ft R-25
Wall [Area/ R-value]	1,600 sq ft/ R-21	1,600 sq ft/ R-16
Window [Area/ R-value]	250/R-3	400/R-2
Floors [Area/ R-value]	2,000/ R-19	2,000/ None
Air Leakage (nach)*	0.35	0.60
Duct Leakage (CFM25)**	50	250
HVAC System Sizing:		
Heating(Btu/hour)	24,600	55,400
Cooling(Btu/hour)	21,200	39,900
Estimated tons of cooling***	2	3.5
Square feet/ton	1,000	570
Typical Equipment Cost:		
Lower Effic. (SEER 10-11)	$3,300	$4,950
Higher Effic. (SEER 11-12)	$4,100	$5,500

* nach means the number of natural air changes per hour the home has due to air leakage.

** CFM25 is the duct leakage rate at a pressure of 25 Pascals — a standard number used during a duct leakage test.

*** there are 12,000 Btu/hour in a ton of cooling.

Table 7-1 compares the size of heating and cooling systems for two homes with identical floor areas. The more efficient home reduces the heating load 55% and the cooling load 43%. Thus, the additional cost of the energy features in the more efficient home is offset by the $600 to $650 savings from reducing the size of the HVAC equipment.

Oversimplified rules of thumb provide oversized heating and cooling systems for more efficient homes. Oversized units cost more to install, increase energy bills, suffer greater wear and tear, and often may not provide adequate dehumidification.

It takes about 15 minutes for most air conditioners to reach peak efficiency. During extreme outside temperatures (under 32^o in winter and over 88^o in summer) the system should run about 80% of the time. Oversized systems cool the home quickly and often do not operate long enough to reach peak efficiency.

Proper sizing includes designing the cooling system to provide adequate dehumidification. In Louisiana's

MANUAL J EXAMPLE*

Manual J, Load Calculation for Residential Winter and Summer Air Conditioning, is published by the Air Conditioning Contractors of America (ACCA.) The procedures in the manual calculate the building heating and cooling loads as follows:

1. Determine all dimensions of the exterior building envelope for each type of surface (wall, floor, window, door, ceiling, etc.).

2. Find R-values of all components.

3. Find the Construction Number of each component based on tables in the book.

4. Look up climatic data in the manual for the locality in which the home is being constructed.

5. Based on the Construction Number and the climatic data, find the Heat Transfer Multiplier (HTM) for the different components during the heating (Htg.) and cooling (Clg.) seasons.

6. Fill in the tables for the heating and cooling load.

7. Calculate the infiltration loads, internal gains, and latent loads in separate charts.

8. Find the grand total loads in Btu/hour.

9. Use ***Manual S, Residential Equipment Selection***, also published by ACCA, to help select the equipment for the home.

1	Name of Room		Entire House
2	Running Ft. Exposed Wall		94.5
3	Room Dimensions Ft.	32	62.5
4	Ceiling Ht. Ft.		8

	TYPE OF EXPOSURE		Const. No.	HTM Htg.	HTM Clg.	Area/ Length	Btuh Htg.	Btuh Clg.
5	Gross Exposed Walls & Partitions	a	12F					
		b						
		c						
		d						
6	Windows & Glass Doors Htg.	a	3b	30.5		300	9,150	
		b						
		c						
		d						
7	Windows & Glass Doors Clg.	North			16	75		1,200
		E&W			46	150		6,900
		South			25	75		1,875
8	Other Doors		10D	23	10.9	42	966	458
9	Net Exposed Walls & Partitions	a	12F	3.5	1.7	1,170	4,095	1,989
		b						
		c						
		d						
10	Ceilings	a	16G	1.6	1.2	2,000	3,200	2,400
		b						
11	Floors	a	19D	1.3	0	2,000	2,600	0
		b						
12	Infiltration HTM						11,757	5,878
13	Sub Total Btuh Loss = 6+8+9+10+11+12						31,768	20,700
14	Duct Btuh Loss			0.1			3,177	2,070
15	**Total Btuh Loss = 13 + 14**						**34,945**	
16	People @ 300 & Appliances= 1200							2,400
17	Sensible Btuh Gain = 7+8+9+10+11+12+16							25,170
18	Duct Btuh Gain				0.05		1,747	1,258
19	**Total Sensible Gain**						**36,692**	**26,428**
	Latent Gain Calculations							
	Latent Infiltration							2,471
	Latent Ventilation							0
	Latent Internal Gains							1,920
	Total Latent Gain							**4,391**

* A *Manual J* calculation takes approximately 30 to 60 minutes for an average home. The measurements for the calculations are available from the construction drawings. *Manual S* calculations require an additional 15 to 30 minutes.

humid climate it is critical to calculate the *latent load* — the amount of dehumidification needed for the home. If the latent load is ignored, the home may become uncomfortable due to excess humidity.

The Sensible Heating Fraction (SHF) designates the portion of the cooling load for reducing indoor temperatures (*sensible cooling*). For example, in a HVAC unit with a 0.75 SHF, 75% of the energy expended by the unit goes to cool down the temperature of indoor air. The remaining 25% goes for latent heat removal — taking moisture out of the air in the home. The Manual J system sizing procedure includes calculations to estimate latent load.

Many homes in Louisiana have design SHFs of approximately 0.7 — 70% of the cooling will be sensible and 30% latent. Systems that deliver less than 30% latent cooling may fail to provide adequate dehumidification in summer.

Temperature Controls

The most basic type of control system is a heating and cooling thermostat. *Programmable thermostats,* also called setback thermostats, can be big energy savers for homes by automatically adjusting the temperature setting when people are sleeping or are not at home. Be certain that the programmable thermostat selected is designed for the particular heating and cooling equipment it will be controlling. This is especially important for heat pumps, as an improper programmable thermostat can actually increase energy bills.

COOLING EQUIPMENT SELECTION

Table 7-2 and 7-3 show equipment charts for two sample air conditioning units. Each system provides a wide range of outputs, depending on the blower speed and the temperature conditions. The SHF in the chart is the Sensible Heating Fraction — the fraction of the total output that cools down the air temperature. The remainder of the output dehumidifies the air — provides latent cooling. Note that both systems provide about 36,000 Btu/ hour of cooling.

System A: with 80° return air, SEER = 12.15
At low fan speed, provides 35,800 Btu/hour, 0.71 SHF, and thus 29% latent cooling (dehumidification).
At high fan speed, provides 38,800 Btu/hour, but a 0.81 SHF, and only 19% latent cooling — not enough dehumidification in many Louisiana homes.

System B: with 80° return air/ SEER = 11.55
At low fan speed, provides 32,000 Btu/ hour, 0.67 SHF and 33% dehumidification.
At high fan speed, provides 35,600 Btu/hour, 0.76 SHF and 24% dehumidification.

Thus, System A, while nominally more efficient than B, provides less dehumidification and potentially less comfort. Varying fan speed can damage equipment and drastically lower efficiency if done by an untrained person without the proper knowledge and equipment to monitor refrigerant pressures.

Table 7-2
Sample Cooling System A Data

Total Air Volume (cfm)	Total Cooling Capacity (Btuh)	Sensible Heating Fraction (SHF)		
		Dry Bulb Temp.		
		75°F	80°F	85°F
950	35,800	0.58	0.71	0.84
1,200	37,500	0.61	0.76	0.91
1,450	38,800	0.64	0.81	0.96

Table 7-3
Sample Cooling System B Data

Total Air Volume (cfm)	Total Cooling Capacity (Btuh)	Sensible Heating Fraction (SHF)		
		Dry Bulb Temp.		
		75°F	80°F	85°F
950	32,000	0.56	0.67	0.78
1,200	34,100	0.58	0.71	0.84
1,450	35,600	0.61	0.76	0.90

Table 7-4
Typical Savings from Programmable Thermostats

Winter Heating Setting	Energy Savings ($/yr)
72˚F Day/72˚F Night	0
72˚F Day/65˚F Night	28
68˚F Day/68˚F Night	48
68˚F Day/60˚F Night	74
68˚F Day/55˚F Night	77

A thermostat should be located centrally within the house or zone. It should not receive direct sunlight or be near a heat-producing appliance. A good location is often 4 to 5 feet above the floor in an interior hallway near a return grille.

The interior wall on which the thermostat is installed, like all walls, should be well sealed at the top and bottom to prevent circulation of cool air in winter or hot air in summer. Some homeowners have experienced excessive energy bills and discomfort for years because air from the attic leaked into the wall cavity behind the thermostat and caused the cooling or heating system to run much longer than needed.

Zoned HVAC Systems

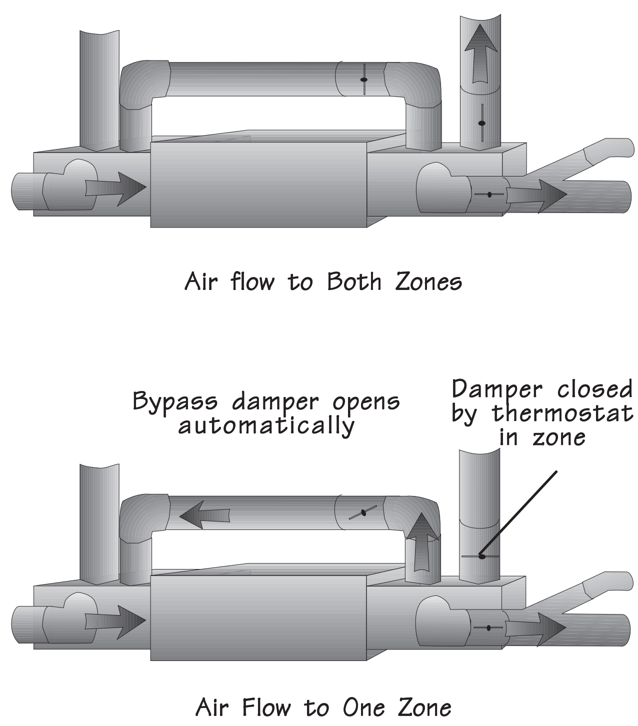
Larger homes often use two or more separate heating and air conditioning units for different floors or areas. Multiple systems can maintain greater comfort throughout the house while saving energy by allowing different *zones* of the house to be at different temperatures. The greatest savings come when a unit serving an unoccupied zone can be turned off.

Rather than install two separate systems, HVAC contractors can provide automatic zoning systems that operate with one system. The ductwork in these systems typically has a series of thermostatically controlled dampers that regulate the flow of air to each zone. Although somewhat new in residential construction, thermostats, dampers, and controls for zoning large central systems have been used for years in commercial buildings.

If your heating and air conditioning subcontractor feels that installing two or three separate HVAC units is necessary, have them also estimate the cost of a single system with damper control over the ductwork. Such a system must be carefully designed to ensure that the blower is not damaged if dampers are closed to several supply ducts. In this situation, the blower still tries to deliver the same air flow as before, but now through only a few ducts. Back pressure created against the blades of the blower may cause damage to the motor. There are three primary design options:

1. Create two zones and oversize the ductwork so that when the damper to one zone is closed, the blower will not suffer damage.
2. Install a manufactured system that uses a dampered bypass duct connecting the supply plenum to the return ductwork. The control system always allows the same approximate volume of air to circulate.
3. Use a variable speed HVAC system. Because variable speed systems are usually more efficient than single-speed systems, they will further increase savings.

Figure 7-2
Automatic Zoned System



AIR CONDITIONING EQUIPMENT

Air conditioners and heat pumps work similarly to provide cooling and dehumidification. In the summer, they extract heat from inside the home and transfer it outside. In winter, a heat pump reverses this process and extracts heat from outside and transfers it inside.

Both systems typically use a vapor compression cycle, which is described in a sidebar on the next page. This cycle circulates a *refrigerant* — a material that increases in temperature significantly when compressed and cools rapidly when expanded. The exterior portion of a typical air conditioner is called the *condensing unit* and houses the *compressor*, the noisy part that uses most of the energy, and the *condensing coil*.

The exterior, air-cooled condensing unit should be kept free from plants and debris that might block the flow of air through the coil or damage the thin fins of the coil. Ideally, locate the condensing unit in the shade. However, do not block air flow to this unit with dense vegetation, fencing or overhead decking.

The inside mechanical equipment, called the *air-handling unit*, houses the *evaporator coil*, the indoor blower, and the *expansion* or *throttling valve*. The controls and ductwork for circulating cooled air to the house complete the system.

The SEER Rating

The cooling efficiency of a heat pump or an air conditioner is rated by the *Seasonal Energy Efficiency Ratio (SEER)*, a ratio of the average amount of cooling provided during the cooling season to the amount of electricity used. Current national legislation mandates a minimum SEER 10.0 for most residential air conditioners. Pending federal policies may further increase minimum efficiencies. Some units can exceed SEER 15.0. Packaged units, which combine the outdoor and indoor components into one package located outside, have a minimum SEER of 9.7.

Builders should be aware that the SEER rating is a national average based on equipment performance in Virginia. Some equipment may not produce the listed SEER in actual operation in Louisiana's homes, particularly during the cooling season.

One of the main problems with HVAC systems has been the inability of some higher efficiency equipment to dehumidify homes adequately. If units are not providing sufficient dehumidification, the typical homeowner response is to lower the thermostat setting. Since every degree the thermostat is lowered increases cooling bills 3 to 7%, systems that have nominally high efficiencies, but inadequate dehumidification, may suffer from higher than expected cooling bills.

In fact, poorly functioning "high" efficiency systems may actually cost more to operate than a well designed, moderate efficiency unit. Make certain that the contractor has used *Manual J* techniques to size the system so that the air conditioning system meets both sensible and latent (humidity) loads at the manufacturer's claimed efficiency.

Variable Speed Units

The minimum standard for air conditioners of SEER 10.0 provides for a reasonably efficient unit. However, higher efficiency air conditioners may be quite economical. Table 7-4 examines the economics of different options for a sample home.

In order to increase the overall operating efficiency of an air conditioner or heat pump, multispeed and variable speed compressors have been developed. These units can operate at low or medium speeds when the outdoor temperatures are not extreme. They can achieve a SEER of 15 to 16.

The cost of variable speed units is generally about 30% higher than standard units. Advantages they offer over standard, single-speed blowers:

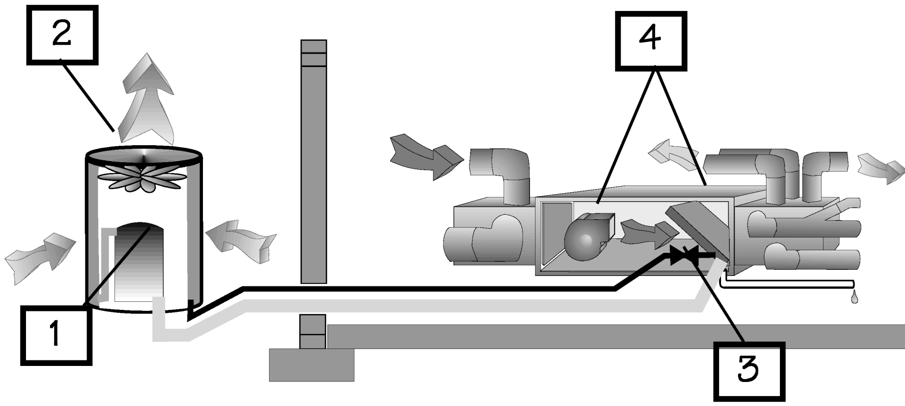
- They usually save energy.
- They are quieter, and because they operate fairly continuously, there is far less start-up noise (often the most noticeable sound in a standard unit).
- They dehumidify better; some units offer a special dehumidification cycle, which is triggered by a humidistat that senses when the humidity levels in the home are too high.

Proper Installation

Too often, high efficiency cooling and heating equipment is improperly installed, which can cause it to operate at substantially reduced efficiencies. A SEER

AIR CONDITIONERS AND HEAT PUMPS

Air Conditioners use the vapor compression cycle, a 4-step process:



1. The compressor (in the outside unit) pressurizes a gaseous refrigerant. The refrigerant heats up during this process.

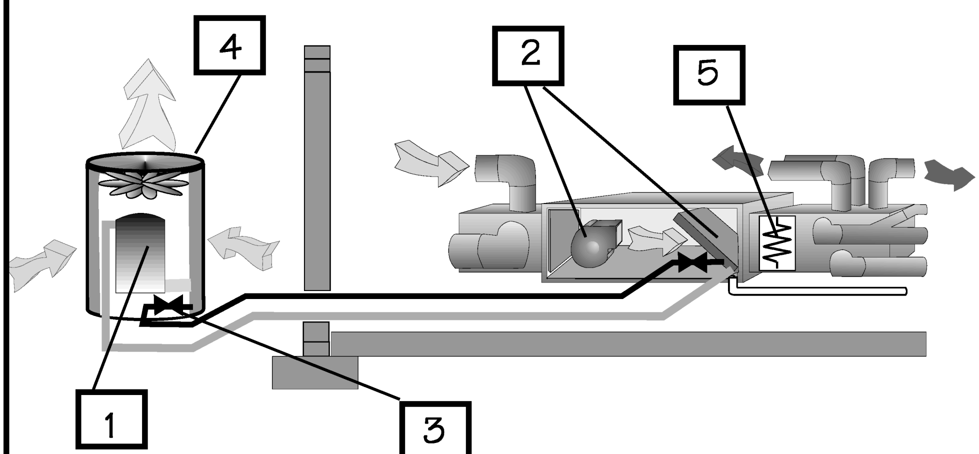
2. Fans in the outdoor unit blow air across the heated, pressurized gas in the condensing coil; the refrigerant gas cools and condenses into a liquid.

3. The pressurized liquid is piped inside to the air-handling unit. It enters a throttling or expansion valve, where it expands and cools.

4. The cold liquid circulates through evaporator coils. Inside air is blown across the coils and cooled while the refrigerant warms and evaporates. The cooled air is blown through the ductwork. The refrigerant, now a gas, returns to the outdoor unit where the process starts over.

Air Source Heat Pumps use a reversed version of the same cycle for heating. A reversing valve allows the heat pump to work automatically in either heating or cooling mode. The steps for heating are:

1. The compressor (in the outside unit) pressurizes the refrigerant, which is piped inside.



2. The hot gas enters the inside condensing coil. Room air passes over the coil and is heated. The refrigerant cools and condenses.

3. The refrigerant, now a pressurized liquid, flows outside to a throttling valve where it expands to become a cool, low pressure liquid.

4. The outdoor evaporator coil, which serves as the condenser in the cooling process, uses outside air to boil the cold, liquid refrigerant into a gas. This step completes the cycle.

5. If the outdoor air is so cold that the heat pump cannot adequately heat the home, supplemental heating must be provided by some other heater. In Louisiana, this is usually a gas fired heater or an electric resistance strip heater.

6. Periodically in winter, the heat pump must switch to a "defrost cycle," which melts any ice that has formed on the outdoor coil.

Packaged systems and room units use the same process in a single box.

Table 7-5
Air Conditioner Economics*
(compared to SEER 10)

Equipment Efficiency	Incremental Energy Savings ($/yr)	Incremental Installed Costs ($)	Annual Rate of Return	Extra Annual Mortgage ($/yr)
SEER 11 (3-ton system)	30	100	31%	8
SEER 12 (3-ton system)	54	200	29%	16
SEER 14 (3-ton system)	92	800	13%	64
SEER 15 (3-ton system)	108	1000	12%	80
SEER 11 (5-ton system)	49	150	35%	12
SEER 12 (5-ton system)	89	250	38%	20
SEER 14 (5-ton system)	153	900	19%	72
SEER 15 (5-ton system)	181	1200	17%	96

* For a system in Baton Rouge. The table assumes energy prices escalate 2% per year.

** Extra annual mortgage for 30-year loan @ 7% annually would be 0.08 times the initial cost.

12 air conditioning system that is installed poorly with leaky ductwork may only deliver a SEER 7. Typical installation problems are:

- *Improper charging of the system* — the refrigerant of the cooling system is the work horse — it flows back and forth between the inside coil and the outside coil, changing states and undergoing compression and expansion. The HVAC contractor should use the manufacturer's installation procedures to charge the system properly. The correct charge cannot be ensured by pressure gauge measurements alone. In new construction, the refrigerant should be weighed in based on the length and size of the refrigerant lines and the HVAC system. Then, use either the supercharge temperature method or, for systems with certain types of expansion valves, the subcooling method to confirm that the charge is correct.
- *Reduced air flow* — if the system has poorly designed ductwork, constrictions in the air distribution system, clogged or more restrictive filters, or other impediments, the blower may not be able to transport adequate air over the indoor coils of the cooling system. Reduced air flow of 20% can drop the operating efficiency of the unit by about 1.7 SEER points; thus, a unit with a SEER of 10.0 would only operate at SEER 8.3.
- *Inadequate air flow to the outdoor unit* — if the outdoor unit is located under an overhang or a deck, or within an enclosure such as fencing or bushes, air may not circulate freely between the unit and outdoor air. In such cases, the temperature of the air around the unit rises, thereby making it more difficult for the unit to cool the refrigerant for the air conditioner. The efficiency of a unit surrounded by outdoor air that is 10 degrees warmer than the ambient outside temperature can drop by over 10%.

For all types of HVAC systems, the best way to ensure proper installation is to include a set of specifications with the plans that dictate the following:

- The system shall be sized for the load using Manual J or other approved methods.
- The refrigerant charge shall be calculated, weighed in, and confirmed using manufacturer's procedures.

- ❒ Ductwork shall be sized using Manual D or other approved method and fully sealed.
- ❒ Make certain supply air has a pathway back to the return. Many home rely on undercut interior doors to let air flow from the room to a central return. However, as discussed in Chapter 8, many rooms, especially those with multiple supply ducts, become pressurized when the HVAC operates. As a consequence, when several interior doors are closed, the main section of the home where the central return is located becomes negatively pressurized. Rooms with more than one supply duct and no return should be connected to the central section of the home with a transfer grille, which permits air flow between the two spaces.
- ❒ The system's operation shall be checked, balanced, and confirmed.

HEATING SYSTEMS

Two types of heating systems are most common in new homes — *furnaces*, which burn natural gas, propane, fuel oil, or electricity and *electric heat pumps*. Furnaces are generally installed with central air conditioners. Heat pumps provide both heating and cooling. Some heating systems are integrated with water heating systems.

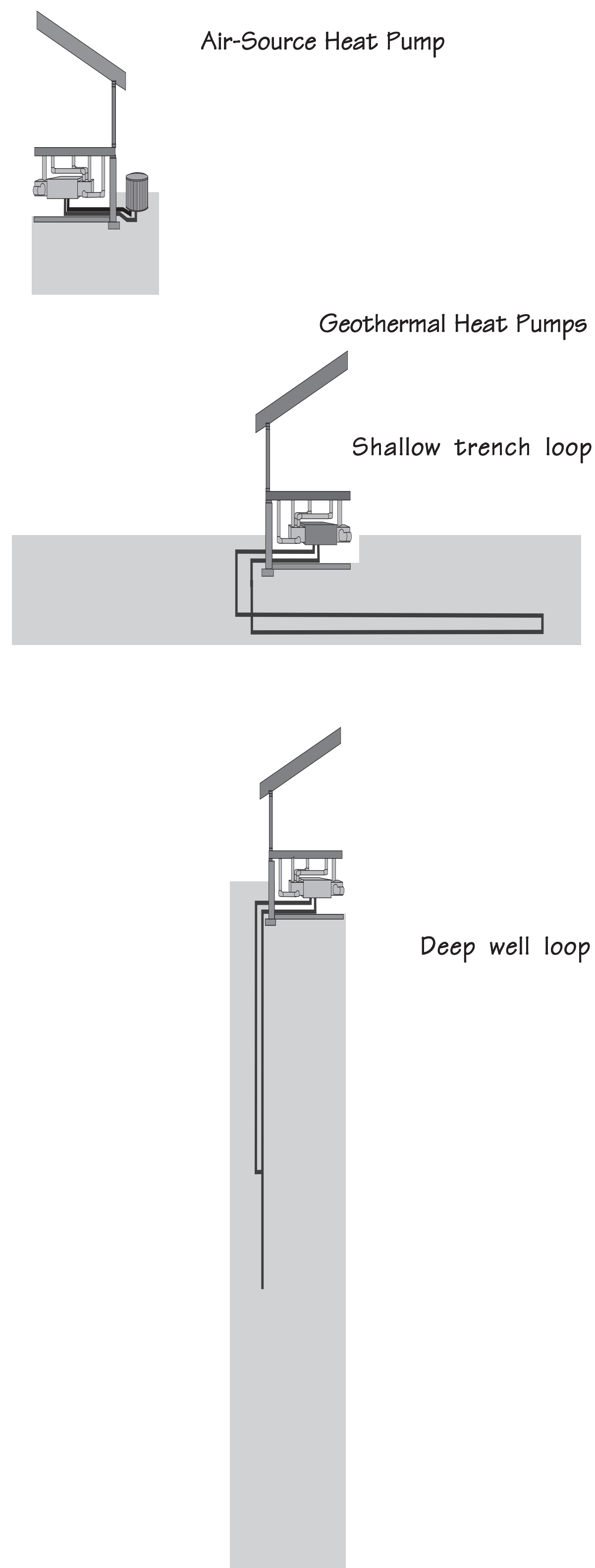
HEAT PUMP EQUIPMENT

Air-source heat pumps

The most common type of heat pump is the *air-source heat pump*, which serves as an air conditioner during the cooling season. In winter, it reverses the cycle and obtains heat from cool outside air. Most heat pumps operate at least twice as efficiently as conventional electric resistance heating systems. They have rated lifetimes of 15 years, compared to 20 years for most furnaces; however, many homeowners have well maintained equipment over 20 years old that continues to work effectively.

At outside temperatures of 25 to 35°F, at a temperature known as the *balance point*, heat pumps can no longer meet the entire heating load of the home. Most systems use electric resistance coils called *strip*

Figure 7–3
Types of Heat Pumps



heaters to provide supplemental backup heat. Strip heaters, located in the air handling unit, are much more expensive to operate than the heat pump itself. They should not be oversized, as they can drive up the peak load requirements of the local electric utility.

A staged, heat pump thermostat used in concert with multistage strip heaters will minimize strip heat operation. *Dual-fuel* or *piggyback* systems heat the home with natural gas or propane when temperatures drop below the balance point.

Air-source heat pumps should have outdoor thermostats, which prevent operation of the strip heaters at temperatures above 38 °F. The International Energy Conservation Code requires controls to prevent strip heater operation during weather when the heat pump alone can provide adequate heating. In addition, tight ductwork is especially important in air-source heat pumps to prevent an uncomfortably low delivery temperature of supply air into the living areas.

Geothermal heat pumps

Unlike an air-source heat pump with its outside coil and fan, a geothermal heat pump relies on fluid-filled pipes buried beneath the earth as a source of heating in winter and cooling in summer. In each season, the temperature of the earth is closer to the desired temperature of the home than outdoor air, so less energy is needed to maintain comfort. Eliminating the outside equipment means higher efficiency, less maintenance, greater equipment life, no noise, and no inconvenience of having to mow around that outdoor unit.

Geothermal heat pumps have SEER ratings above 15 and can save up to 40% on the heating and cooling costs for a standard air-source heat pump. Some geothermal products have greater dehumidification ability as well. Many units can also provide hot water at much greater efficiency than standard electric water heaters. Because of the warmer temperatures of the earth, geothermal heat pumps deliver heated air in winter to the home between 95 to 110°F.

Types of closed loop designs for piping include:

- In deep well systems, a piping loop extends several hundred feet under ground.
- Shallow loops are placed in long trenches, typically about 6-feet deep and several hundred feet long; coiling the piping into a "slinky" reduces the length requirements but a relatively large ground area is required.
- For homes located on private lakes, loops can be installed on the bottom, which decreases the installation costs.

The buried piping in geothermal systems usually has a 25-year warranty. Most experts believe the piping will last longer, because it is made of a durable plastic with heat-sealed connections, and the circulating fluid has an anticorrosive additive.

Geothermal heat pumps cost $800 to $1,400 more per ton to install than air-source units. The actual cost varies according to the difficulty of installing the ground loops as well as the size and features of the equipment.

Table 7- 6
Economic Analysis of Heat Pumps*
(compared to HSPF 6.8/ SEER 10)

Equipment Type and Efficiency	Incremental Energy Savings ($/yr)	Incremental Installed Costs ($)	Annual Rate of Return	Incremental Mortgage Costs**
SEER 11 (3 tons) / HSPF 7.2	49	200	26.5%	16
SEER 12 (3 tons) / HSPF 7.5	86	400	23.5%	32
SEER 14 (3 tons) / HSPF 7.2	145	750	21.2%	145
3-ton Geothermal System (with water heating)	367	3,600	11.5%	287
SEER 11 (5 tons) / HSPF 7.2	82	300	29.2%	24
SEER 12 (5 tons) / HSPF 7.5	144	650	24.1%	52
SEER 14 (5 tons) / HSPF 7.2	241	1,000	26.0%	80
5-ton Geothermal System (with water heating)	611	6,000	11.5%	479

*For a system in Baton Rouge. Table assumes energy prices escalate 2% per year.
**Extra annual mortgage for 30-year loan @ 7% annually would be 0.08 times the initial cost.

Because of their high installation cost, geothermal heat pumps may not be economical for homes with low heating and cooling needs. However, their lower operating costs, reduced maintenance requirements, and greater comfort may make them attractive to many homeowners. Proper installation of the geothermal loops is essential for high performance and the longevity of the system, so choose only qualified, experienced geothermal heat pump contractors.

Measures of efficiency for heat pumps

The heating efficiency of a heat pump is measured by its *Heating Season Performance Factor* (HSPF), which is the ratio of heat provided in Btu per hour to watts of electricity used. This factor considers the losses when the equipment starts up and stops, as well as the energy lost during the defrost cycle. The HSPF averages the performance of heating equipment for a typical winter in the United States, so the actual efficiency will vary in different climates.

Typical values for the HSPF are 6.8 for standard efficiency, 7.2 for medium efficiency, and 8.0 for high efficiency. Variable speed heat pumps have HSPF ratings as high as 9.0. Geothermal heat pumps are not rated by HSPF as yet; however, they are much more efficient than air heat pumps and work well at sub-zero temperatures. They are also quieter than conventional systems and include water heating capabilities. The ARI Directory of Air Conditioning Equipment lists the efficiencies of many different products.

Furnace Equipment

Furnaces burn fuels such as natural gas, propane, and fuel oil to produce heat and provide warm, comfortable indoor air during cold weather in winter. They come in a variety of efficiencies. The comparative economics between heat pumps and furnaces depend on the type of fuel burned, its price, the home's design, and the outdoor climate. Recent increases in energy prices have improved the economics of more efficient heating and cooling systems. However, at this point in time it is difficult to compare furnaces and heat pumps of various types due to long-term fuel price uncertainty.

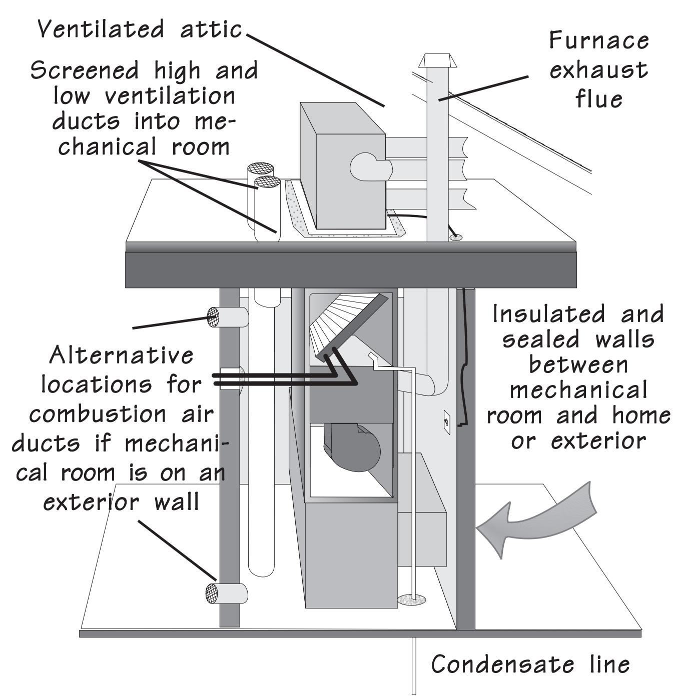
Furnace operation

Fuel-fired furnaces require oxygen for combustion and extra air to vent exhaust gases. For many years, atmospheric or natural draft furnaces were the standard. These units draw in air from around them whether located in the house, crawlspace or attic. They have a single, unsealed exhaust stack to carry the hot exhaust gases out of the home. Older units used a continuously burning gas flame as a pilot light to ignite the fuel when the home's thermostat detected a need for heat.

Homes today are generally built much tighter, have central air conditioning, and a variety of exhaust fans including range hoods, bathroom exhaust fan, and clothes dryers. As discussed in Chapter 3 (see page 44) and in Chapter 8 on ductwork, operating exhaust fans and even closing interior doors can cause negative pressure in the area around the furnace, especially in tighter homes. If the negative pressure is sufficiently high, the furnace may backdraft, pulling the exhaust gases down the flue and into the home and creating potentially deadly levels of carbon monoxide.

Because negative pressures can occur in virtually any home, atmospheric furnaces should not be installed in the conditioned space. If located inside the conditioned area of a home, they must be installed in a sealed and insulated closet, as shown in Figure 7-4, with two sources of incoming combustion air--one entering near the floor and the other near the ceiling. The unit must include an exhaust vent that extends through the roof.

Figure 7-4
Sealed Mechanical Room Design for Non-direct Vent Furnace



More modern furnaces, known as direct vent or uncoupled furnaces, have a duct that supplies combustion air from the outside directly to the burner and a sealed exhaust vent to the outside. Because their combustion system is totally isolated from the living space, these units can operate safely inside a home, when in proper working order. They are recommended unless the furnace is completely outside the conditioned area of the home.

Measures of efficiency for furnaces

The efficiency of a gas furnace is measured by the Annual Fuel Utilization Efficiency (AFUE), a rating which takes into consideration losses from pilot lights, start-up, and stopping. Unlike SEER and HSPF ratings, the AFUE does not consider the unit's electricity use for fans and blowers, which may exceed $50 annually.

An AFUE rating of 78% means that for every $1.00 worth of fuel used by the unit, $0.78 worth of usable heat is produced. The remaining $0.22 worth of energy is lost as waste heat exhausted up the flue.

Several years ago, the federal government mandates that furnaces have AFUE ratings of at least 78%. Old, atmospheric furnaces with pilot lights had AFUE ratings of only 50 to 60%. Manufacturers were able to meet the new standard by first replacing pilot lights with electronic ignition. Some of these units are able to operate at an AFUE of 78% and are being sold today in Louisiana.

Most manufacturers took the next steps of improving the heat exchanger inside the unit and installing a fan to force exhaust gases out of the flue. These furnaces are usually *non-direct vent* units because they do not have a sealed source of combustion air. They must be treated in the same manner as atmospheric furnaces, as described in the previous section. However, they are much less susceptible to backdrafting because of the fan for exhausting flue gases. Their AFUE ratings are typically 80% to 83%.

Models with efficiencies over 90% and up to 97%, commonly called *condensing furnaces*, contain secondary heat exchangers that actually cool flue gases until they partially condense. Heat losses up the flue are virtually eliminated. A drain line connected to the flue drains the condensate. One advantage of cooler exhaust gas is that you can use a plastic flue pipe that can be vented horizontally through a side wall. Metal flues, sometimes required by code, will quickly corrode when used with these high efficiency units. Make sure your local building official is aware of the need to install a plastic flue before ordering a condensing furnace.

There are a variety of condensing furnaces available. Some rely primarily on the secondary heat exchanger to increase efficiency, while others, such as the *pulse furnace,* have revamped the entire combustion process.

Because of the wide variety of condensing furnaces on the market, compare prices, warranties, and service. Also, compare the economics carefully with those of moderate efficiency units. Condensing units may have longer paybacks than expected in energy efficient homes due to reduced heating loads.

Table 7-7
Economic Analysis of Gas Furnaces*
(compared to AFUE .78)

Type of Treatment	Incremental Energy Savings ($/yr)	Incremental Installed Costs ($)	Annual Rate of Return	Incremental Mortgage Costs ($/yr) **
AFUE .80 (36,000 Btuh)	10	100	8%	9
AFUE .95 (36,000 Btuh)	47	650	n/a	52
AFUE .80 (60,000 Btuh)	15	125	13%	10
AFUE .95 (60,000 Btuh)	78	750	12%	60
AFUE .95 (60,000 Btuh — Shreveport)	105	750	16%	60

*For a system in Baton Rouge. Table assumes energy prices escalate 2% per year.
**Extra annual mortgage for 30-year loan @ 7% annually would be 0.08 times the initial cost.

Table 7-7 evaluates the economics of various gas furnaces for the Baton Rouge climate. The savings from more efficient heating systems are marginal due to the mild winters. Note that in Shreveport, as shown by the last example in the table, the economics improve because of the longer, colder heating season.

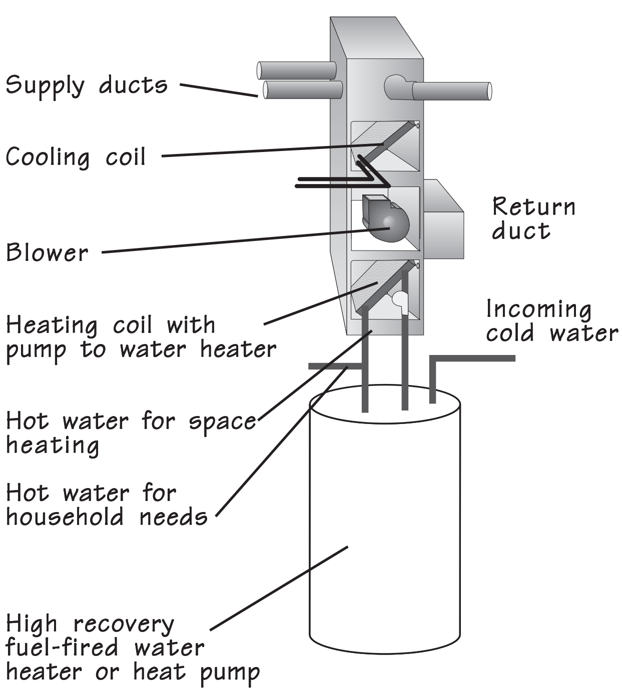
Gas-fired integrated systems

One type of integrated space and water heater system uses a quick recovery, high efficiency gas water heater to provide 140°F water that provides space heating and hot water. Heating needs are met by pumping hot water from the water heater to a heating

Integrated Space and Water Heating

An integrated space heating and domestic water heating unit provides a single, multipurpose system. The American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) has developed standards by which to evaluate such systems, as well as methods of measuring the efficiency of integrated systemswith either space heating or water heating as their primary purpose.

Figure 7-5
Integrated Space and Water Heating System



coil in the air handling unit.

Household air passing through ductwork connected to this coil is heated to between 110 and 120°F. The water, cooled to about 120°F by the air, returns from the heating coil to the integrated water heater for reheating. The air handler can also incorporate a cooling coil for air conditioning. The economics of these units can be quite favorable; however, it is often difficult to obtain an objective comparison between integrated systems and more conventional space and water heating equipment.

Some advantages of integrated systems are:

- ❒ They can save floor space, as some air handling units mount to the wall or within the wall cavity above the water heater tank.
- ❒ They may have lower installed costs — only one gas hookup and a single flue are required.
- ❒ They often have a more efficient water heater than standard homes.

Another integrated approach uses a central boiler to provide space and water heating. Typically, the boiler can provide hot water even in nonheating seasons more efficiently than standard water heaters. However, the greater initial cost of this type of system may limit its use to families with high hot water demands.

Electric integrated systems

There are several products that use central heat pumps for water heating, space heating and air conditioning. These integrated units are available in both air-source and geothermal models.

Make sure the unit is not substantially more expensive than a separate energy efficient heat pump and electric water heater . Units within $1,500 may provide favorable economic returns. The SEER of the unit should exceed 10.0.

To be a viable choice, any type of integrated system should:

- ❒ Have a proven track record in the field.
- ❒ Cost about the same, if not less, than comparable heating and hot water systems of ap-

proximately the same efficiencies.

- ❒ Provide at least a five-year warranty.
- ❒ Be properly sized for both the heating and hot water load.

Wood Heating

Wood can be a thrifty alternative to conventional heating sources. However, if the homeowner must purchase wood fuel, the savings will diminish. Wood heating also requires work, and a fire-safe installation is essential.

Although there are wood-burning furnaces designed for homes, most homeowners interested in wood heating use a fireplace or wood heater — either freestanding stove or fireplace insert. Fireplaces and wood heaters are primarily space heaters. They radiate heat to people and objects close by and, to a lesser degree, heat the surrounding air.

Like other fuel-burning equipment, fireplaces and wood heaters need air for combustion and must vent exhaust products to the outside. In standard construction, air infiltration provides the necessary combustion air. However, in energy efficient homes, the sources of air infiltration are greatly reduced so special measures to supply outside combustion air must be provided.

An energy efficient fireplace must have a direct vent that brings air from outside the home to the firebox. The vent should be designed so that it remains clear of ashes, wood, and other materials when a fire is burning. It should be located toward the front of the firebox and have a damper or lid that prevents infiltration when the fireplace is not in use.

In addition to an outside source of combustion air, a fireplace should have a tight-fitting flue damper and glass doors to reduce air leakage further. The flue damper should be opened before lighting a fire and closed after combustion is complete.

Some fireplace designs provide a means of heating room air by circulating it around the firebox where it is heated and then passed back into the house. These systems are more efficient than standard fireplaces.

Homeowners serious about using wood as a heat source should choose a high efficiency wood heater, such as an airtight wood stove. As with fireplaces, wood heaters in energy efficient homes should have an outside source of combustion air. In fact, even standard houses may not have adequate infiltration levels to maintain proper combustion and venting for a wood heater.

To ensure safety, select a wood heater designed to use outside combustion air. These units are required by code in manufactured housing and are usually sold by businesses supplying wood heaters and fireplaces. The wood heater should also be properly sized for the home. Many energy efficient homes have small heating loads,

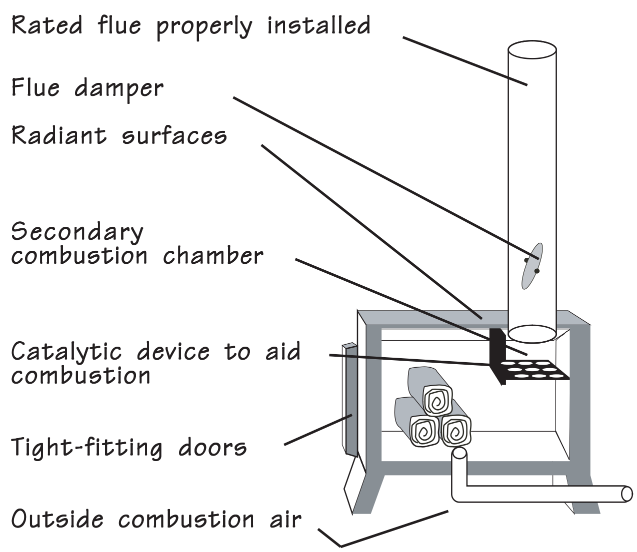
Table 7-8
Typical Wood Heating Savings ($/year)*

Size of Home (sq ft)	Backup Heating Efficiency	% of Heating Needs Supplied: 25%	50%	75%	100%
1,200	Moderate **	56	112	167	223
	High	48	97	145	193
1,800	Moderate	80	160	240	320
	High	69	139	208	277
2,400	Moderate	105	209	314	418
	High	91	181	272	362
3,200	Moderate	137	274	411	548
	High	119	237	356	475

* Wood is assumed to cost the consumer $3 per million Btu; the efficiency of a wood stove is assumed to be 50%.

** Moderate efficiency units: Gas furnace AFUE is 0.78 to 0.80/

Figure 7-6
Efficient Wood Heater Design



so large or even moderate-sized wood heaters may produce too much heat.

Unvented Fuel-Fired Heaters

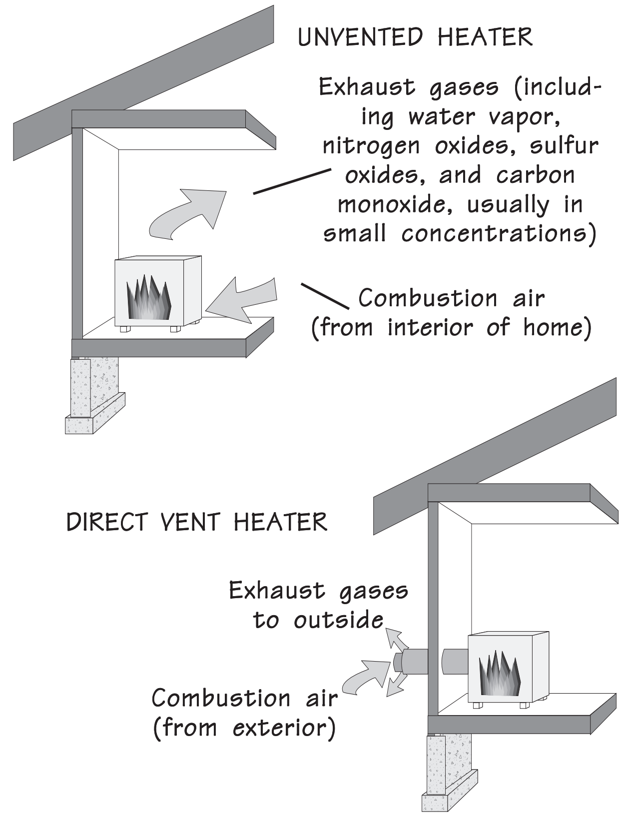
Unvented heaters that burn natural gas, propane, kerosene, or other fuels are strongly discouraged. While these devices usually operate without problems, the consequences of a malfunction are life-threatening — they can exhaust carbon monoxide directly into household air. They also can create serious moisture problems inside the home and exhaust nitrogen oxides.

Most devices come equipped with alarms designed to detect air quality problems. However, many experts question putting a family at any risk of carbon monoxide poisoning — they see no rationale for bringing these units into a home. There are a wide variety of efficient, vented space heaters available.

Examples of unvented units to avoid include:

- ❒ Flueless gas fireplaces — use sealed combustion, direct vent units instead
- ❒ Room space heaters — choose forced-draft, direct-vent models instead

Figure 7-7
Unvented and Direct Vent Heaters



VENTILATION AND INDOOR AIR QUALITY

All houses need ventilation to remove stale interior air and excessive moisture. There has been considerable concern recently about how much ventilation is required to maintain the quality of air in homes. The sidebar on Indoor Air Quality addresses some of the major issues. While there is substantial disagreement on the severity of indoor air quality problems, most experts agree that the solution is <u>not</u> to build an inefficient, "leaky" home.

Research studies show that standard houses are almost as likely to have indoor air quality problems as energy efficient ones. Most building researchers believe that no house is so leaky that the occupants can be relieved of concern about indoor air quality. They recommend mechanical ventilation systems for all houses.

The amount of ventilation required depends on the number of occupants and their lifestyle, as well as the design of the home. The ASHRAE standard, "Ventilation for Acceptable Indoor Air Quality" (ASHRAE 62) recommends that houses have 0.35 natural air changes per hour (nach) or 15 cubic feet per minute of ventilation per occupant.

Older, drafty houses can have infiltration rates of 1.0 to 2.5 nach. Standard homes built today are tighter and usually have rates of from 0.5 to 1.0 nach. New, energy efficient homes often have less than 0.35 nach.

Infiltration is not a successful means of ventilation because it is not reliable and the quantity of incoming air is not controllable. Air leaks are unpredictable, and infiltration rates for all houses vary. For example, air leakage is greater during cold, windy periods and can be quite low during muggy, hot weather. Thus, pollutants may accumulate during periods of calm weather even in drafty houses. These homes will also have many days when excessive infiltration provides too much ventilation, causing discomfort, high energy bills, and possible deterioration of the building envelope.

Concerns about indoor air quality are leading more and more homeowners to install controlled ventilation systems that provide a reliable source of fresh air. The simplest approach is to provide spot ventilation of bathrooms and kitchens to control moisture. Nearly all exhaust fans in standard construction are ineffective — a prime contributor to moisture problems in Louisiana homes. Builders should select quality fans with low noise ratings.

General guidelines call for providing a minimum of 50 cubic feet per minute (cfm) of air flow for baths and 100 cfm for kitchens. Manufacturers should supply the cfm rating for any exhaust fan.

The cfm rating typically assumes the fan is working against an air pressure resistance of 0.1 inch of water — the resistance provided by about 15 feet of straight, smooth metal duct. In practice, most fans are vented with flexible duct that provides much more resistance. Many ventilation experts suggest choosing a fan based on a resistance of 0.30 inches of water.

While larger fans cost more, they are usually better constructed and therefore last longer and run quieter. The level of noise for a fan is rated by *sones*. Choose a fan with a sone rating of 1.5 or less. Top quality models are often below 0.5 sones.

Many ceiling- or wall-mounted exhaust fans can be adapted as "in-line" blowers located outside of the living area, such as in an attic or basement. Manufacturers also offer in-line fans to vent a single bath or kitchen, or multiple rooms. Distancing the in-line fan from the living area lessens noise problems.

Bath and kitchen exhaust fans should vent to the outside — not just into an attic or crawlspace. Avoid side-vented stove units whose exhaust fans pull 400 to 700 cfm from the house. Unless some form of make-up air is supplied, these units can create high levels of negative pressure.

Always test a home for pressure imbalance problems when fans are operating. In tighter homes, a single bathroom exhaust fans may backdraft fireplaces or combustion appliances. If pressure problems exist, the home should have a source of make-up air, which is described in the next section.

While improving spot ventilation will certainly help control moisture problems, it may not provide adequate ventilation for the entire home. A *whole house ventilation system* can exhaust air from the kitchen, all baths, and perhaps the living area or bedrooms.

Figure 7-8
Ventilation with Spot Fans

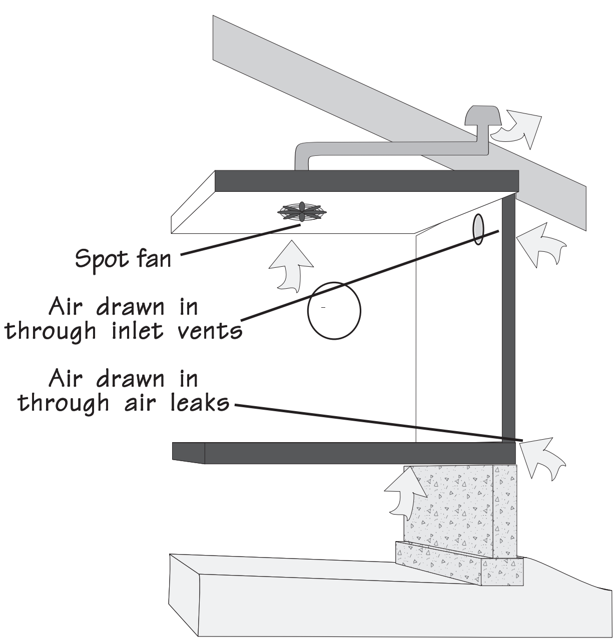
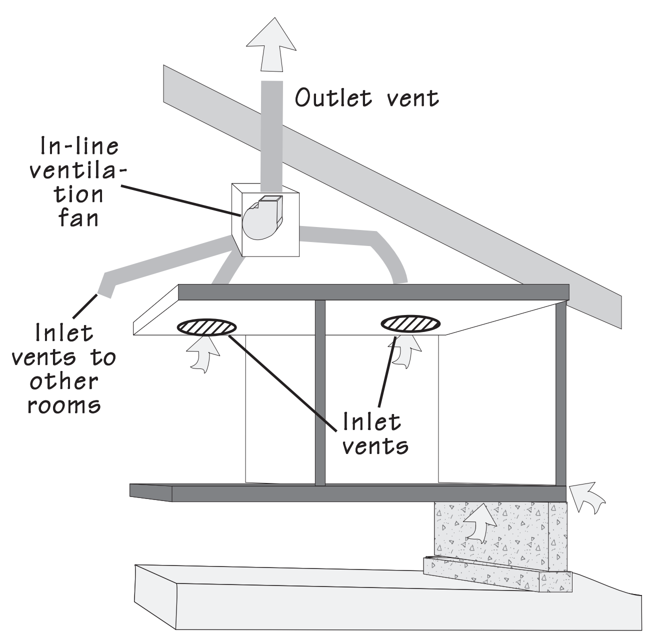


Figure 7-9
In-Line Ventilation Fans



Whole house ventilation systems usually have large single fans located in the attic or basement. Ductwork extends to rooms requiring ventilation. These units typically have two-speed motors. The low speed setting gives continuous ventilation — usually 10 cfm per person or 0.35 ach. The high speed setting can quickly vent moisture or odors.

Supplying Outside Make-up Air

From air leaks

The air vented from the home by exhaust fans must be replaced by outside air. Air leaks can provide the make-up air, but it is far better to provide a controlled mechanism for make-up air as an integral part of the house design. Relying on air leaks requires no extra equipment; however, the occupant has little control over the air entry points. Plus, many of the air leaks come from undesirable locations, such as crawlspaces or attics. If the home is too airtight, the ventilation fans will not be able to pull in enough outside air to balance the air being exhausted. It will generate a negative pressure in the home, which may cause increased wear on fan motors. Plus, the exhaust fans may threaten air quality by pulling exhaust gases from flues and chimneys back into the home. The homeowner can alleviate the pressure problems by opening windows slightly though this may pose a home security risk.

From inlet vents

Providing fresh outside air through inlet vents is another option. These vents can often be purchased from energy specialty outlets by mail order. They are usually located in exterior walls. The amount of air they allow into the home can be controlled manually or by humidity sensors.

Locate inlet vents where they will not create uncomfortable drafts. They are often installed in bedroom closets with louvered doors or high on exterior walls. Ideally, they should be filtered and located as far as possible from all exhaust vents.

Via ducted make-up air

Outside air can also be drawn into and distributed through the home via the ducts for a forced-air heating and cooling system. This type of system usually has an automatically controlled outside air damper in the return duct system.

The blower for the ventilation system is either the air handler for the heating and cooling system or a smaller unit that is strictly designed to provide ventilation air. A disadvantage of using the HVAC blower is that incoming ventilation air may have sufficient velocity to affect comfort conditions during cool weather.

The ductwork for the heating and cooling system may be connected to a small outside return air duct with a damper that opens either when the ventilation fan operates or when the house goes to a negative pressure. The resulting reduced air flow should not adversely affect comfort.

Dehumidification Ventilation Systems

Louisiana homes are often more humid than desired. A combined ventilation-dehumidifier system can bring in fresh, outdoor air, remove its moisture, and supply it to the home. These systems can also filter incoming air. Because these systems require an additional mechanical device — a dehumidifier installed on the air supply duct — they should be designed for the specific needs of the home.

Heat Recovery Ventilators

Air-to-air heat exchangers, or heat recovery ventilators (HRV — described in Figure 7-10), typically have separate duct systems that draw in outside air for ventilation and distribute fresh air throughout the house. In winter, heat from stale room air is "exchanged" to the cooler incoming air. In summer, the hot outdoor air is cooled and may be partially dehumidified by the cooler exhaust air. Some models, called *enthalpy* heat exchangers, can also recapture cooling energy in summer by exchanging moisture between exhaust and supply air.

While energy experts have questioned the value of the heat saved in Louisiana homes for the $400 to $1,500 cost for an HRV, recent studies on enthalpy units indicate their dehumidification benefit in summer offers an advantage over ventilation-only systems. The value of any heat recovery ventilation system should not be determined solely on the cost of recovered energy — the controlled ventilation and improved quality of the indoor environment must be considered as well.

SAMPLE VENTILATION PLANS

Design 1: Upgraded Spot Ventilation

This relatively simple and inexpensive whole house ventilation system integrates spot ventilation using bathroom and kitchen exhaust fans with an upgraded exhaust fan (usually 100 to 150 cfm) in a centrally located bathroom. When the fan operates, outside air is drawn through inlets in closets with louvered doors. The fan is controlled by a timer set to provide ventilation at regular intervals. Interior doors are undercut to allow air flow to the central exhaust fan. The fan must be a long-life, high-quality unit that operates quietly. In addition to the automatic ventilation provided by this system, occupants can turn on all exhaust fans manually as needed.

Design 2: Whole House Ventilation System

This whole house ventilation system uses a centralized two-speed exhaust fan to draw air from the kitchen, bath, laundry, and living area. The blower is controlled by a timer. The system should provide approximately 0.35 ach on low speed and 1.0 ach on high speed. Outside air is supplied by a separate dampered duct connected to the return air system. When the exhaust fan operates, the outside air damper opens and allows air to be drawn into the house through the forced-air ductwork.

Design 3: Heat Recovery Ventilation (HRV) System

HRV's draw fresh outside air through ducts into the heat exchange equipment and recaptures heating or cooling energy from stale room air as it is being exhausted. Some systems, called enthalpy heat exchangers, also dry incoming humid air in summer — a particular benefit in the Southeast. Fresh air flows into the house via a separate duct system, which should be sealed as tightly as the HVAC ductwork. Exhaust room air can either be ducted to the exchanger from several rooms or a single central source.

Figure 7-10
Sample Ventilation Plans